CHEMOSYSTEMATIC AFFINITIES OF A CALIFORNIA POPULATION OF ABIES LASIOCARPA

EDWARD A. COPE
L. H. Bailey Hortorium, Cornell University,
Ithaca, NY 14853-0271

ABSTRACT

A California population of *Abies lasiocarpa* has volatile leaf oil composition similar to an Oregon Cascade population. Both are distinct from a Colorado population that contains greater percentages of santene, *alpha*-pinene and camphene and smaller relative proportions of *beta*-phellandrene and limonene.

Subalpine fir, *Abies lasiocarpa* (Hook.) Nutt., is a western cordilleran species of major importance in high elevation forests (Fowells 1965). In the Rocky Mountains it is abundant along with *Picea engelmannii* Parry ex Engelm. and *Pinus contorta* Dougl. ex Loud. In the Cascade Range its associates are *Abies amabilis* (Dougl.) Forb. and *Tsuga mertensiana* (Bong.) Carr. (Franklin and Dyrness 1973, Liu 1971). The range of the species in the Cascades is more or less continuous southward to 44°N except for the Columbia River gap. Three disjunct populations occur at lower latitudes in Oregon and California (Sawyer et al. 1970, Sawyer and Cope 1982). These populations grow in the Klamath Mountains, a region that is geologically (Oakeshott 1971) and floristically (Whittaker 1961) distinct from the volcanic Cascades of Oregon and northern California. The southernmost California population is separated from the Cascade trees by some 180 km.

Subalpine fir shows considerable geographic variation morphologically and chemically, especially in volatile oil composition (Hunt and von Rudloff 1974, 1979; Zavarin et al. 1970). Analysis of terpenes of leaves and cortex (Hunt and von Rudloff 1974, 1979; von Rudloff 1975, Zavarin and Snajberk 1972, Zavarin et al. 1971) also showed that *Abies lasiocarpa* introgresses with *Abies balsamea* (L.) Miller in Canada. The taxonomic conclusions vary. Boivin (1959) proposed varietal status for *A. lasiocarpa,* and Hunt and von Rudloff (1979) suggested the recognition of three species, *A. balsamea, A. bifolia* Murr., and *A. lasiocarpa.* Comparison of Klamath Mountains populations with those of the Oregon Cascades and Rocky Mountains adds information by describing subalpine fir at its southwestern range limit.

MADROÑO, Vol. 30, No. 2, pp. 110–114, 20 April 1983

TABLE 1. PERCENT OF TOTAL LEAF TERPENE COMPOSITION OF THE MEANS AND RANGES OF FOUR *Abies lasiocarpa* POPULATIONS. Terpenes listed in order of elution on SE-30 column. Albertan population values listed from Hunt and von Rudloff (1974). Values listed across from suspected major component of each group where terpenes did not sufficiently separate. Albertan means grouped where necessary. + = terpene present in amounts less than 0.1%. – = terpene not detectable.] = grouped. * = may not be present in Colorado, Oregon, and California samples.

Peak number	Terpene or terpene group	Colorado		Alberta			Oregon		California	
		Range	Mean	Range	Mean	Groups	Range	Mean	Range	Mean
1.	Santene	0.8–3.0	2.2	1.8–3.9	3.1		—	—	—	—
2.	Tricyclene			0.6–1.5	1.0	5.8				
3.	*alpha*-Pinene	3.6–7.9	5.7	3.7–6.4	4.8		1.4–3.3	2.5	1.1–3.0	2.1
4.	Camphene	11.3–24.5	17.0	7.3–16.2	12.5		+–+	+	+–0.4	0.2
5.	*beta*-Pinene	7.1–27.7	19.4	8.5–22.8	12.0	13.1	12.2–35.5	19.1	11.6–19.4	15.6
6.	Myrcene*			0.8–1.5	1.1					
7.	*delta*-3-Carene	—	—	+–0.3	+		+–0.2	0.2	0.2–1.3	0.9
8.	Limonene			5.1–20.2	11.2					
9.	*beta*-Phellandrene	10.2–43.0	26.8	10.0–29.0	20.9	32.9	53.1–75.4	63.0	56.9–67.9	64.0
10.	*trans*-Ocimene			0.4–1.8	0.7					
11.	Terpinolene	0.3–2.1	1.1	0.6–1.1	0.9		+–0.4	0.2	+–2.7	0.8
12.	Borneol*			0.1–0.7	0.4					
13.	Terpinen-4-ol*	0.2–1.2	0.4	+–0.2	0.1	0.7	––+	+	+–2.0	0.5
14.	*alpha*-Terpineol*			0.1–0.3	0.2					
15.	Piperitone	—	—	1.2–4.8	3.2		0.3–5.0	2.4	2.5–8.0	4.8
16.	Bornyl acetate	14.2–50.0	27.4	13.0–31.6	22.8		2.1–15.4	9.6	3.5–16.3	9.9
17.	Methyl thymol*			0.3–3.7	1.2	24.9				
18.	Thymol*			0.2–1.9	0.9					
19.	Unidentified	—	—				––+	+	––0.7	0.3
20.	Unidentified (C15)]	+–0.6	0.3				1.8–10.2	5.1	+–3.6	1.7
21.	Unidentified (C15)]									

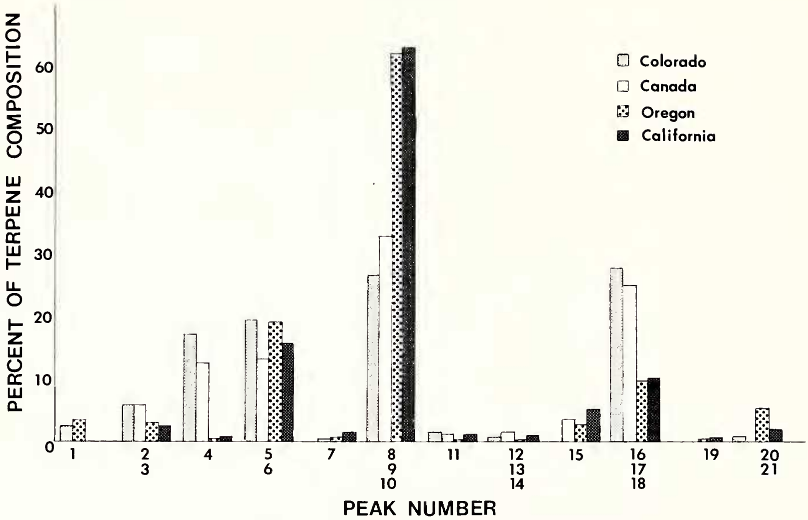

FIG. 1. Percent of total terpene composition in order of elution of each terpene or terpene group from SE-30 column.

METHODS

Samples containing leaves only were taken in September and early October 1977 from: 9 trees at 2050 m elevation from the edges of Little Duck Lake, Siskiyou County, California (123°W, 41°30′N); 5 trees at 2150 m on rocky slopes surrounding O'Dell Butte Lookout station, Klamath County, Oregon (122°W, 43°30′N); and 5 trees at 3400 m in moist meadow edges, Park County, Colorado (106°W, 39°N). Procedures for collection, transportation, storage and preparation for monoterpene analysis of leaf oil using gas-liquid chromatography followed Hunt and von Rudloff (1974).

After steam distillation, quantitative runs were made on two CLC columns (3% SE-30, 60-80 mesh Gaschrom Q, inside diameter 2.5 mm, length of 300 mm; 2% Carbowaxx 20M and 1% OV17, 80-100 mesh Chromasorb G-H.P. with inside diameter 2.5 mm, length of 300 mm).

Relative percentages of the monoterpenes were determined by integration of peak areas. It was necessary in some cases to calculate percentages for groups of terpenes because not all terpenes were separated sufficiently for individual calculation of terpene amount. Error in peak area calculation was estimated to vary from 1% (major peak representing at least 50% of the sample) to 30% (minor peaks representing less than 2% of the sample).

TABLE 2. RANGES OF TWO TERPENES AND TWO TERPENE GROUPS SEPARATING ALBERTA AND COLORADO POPULATIONS OF *Abies lasiocarpa* FROM CALIFORNIA AND OREGON POPULATIONS.

Peak no.	Terpene or terpene group	Oregon and California	Alberta and Colorado
1.	Santene	0	0.8–3.9
2.3.	*alpha*-Pinene	1.1–3.3*	3.6–7.9
4.	Camphene	trace–0.4	7.3–24.5
8.9.10.	*beta*-Phellandrene	53.1–75.4	10.0–51.5

* Hunt and von Rudloff's (1979) values are higher (3.5–4.5) for their coastal sample, thus overlapping with Rocky Mountain *alpha*-Pinene data.

RESULTS AND DISCUSSION

Table 1 lists the range and mean for each terpene in order of its elution. Hunt and von Rudloff's (1974) data from Alberta are included for comparison. Terpenes that did not permit individual calculation of percentages are tricyclene and *alpha*-pinene (Peaks 2 and 3), *beta*-pinene and myrcene (Peaks 5 and 6), limonene, *beta*-phellandrene and *trans*-ocimene (Peaks 8, 9 and 10), bornyl acetate, methyl thymol and thymol (Peaks 16, 17 and 18) and the sesquiterpenes (Peaks 20 and 21). These peaks are designated by their suspected major components, *alpha*-pinene, *beta*-pinene, *beta*-phellandrene and bornyl acetate, respectively. The percentages of these groups are listed (Table 1) and graphed (Fig. 1) by group. Hunt and von Rudloff's (1974) data are grouped where appropriate by adding percentages of the individual terpenes involved.

The relative amounts of monoterpenes of the Klamath Region population of California are similar to those of the Oregon Cascades. The *beta*-phellandrene group, santene, camphene, the *alpha*-pinene group and the bornyl acetate group in the Klamath and Cascade populations are similar in percent of the total terpene composition (Fig. 1). There are substantial monoterpene differences between these populations and the Rocky Mountain populations of both this work and Hunt and von Rudloff's (1974, 1979) studies.

The distinctive character of the volatile oil composition of Rocky Mountain populations in comparison to Klamath/Cascade populations is shown in Table 2. The western populations have no detectable santene, an *alpha*-pinene group of less than 3.5% (contrasting with Hunt and von Rudloff's (1979) *alpha*-pinene range of 3.5–4.5%), a trace of camphene and a *beta*-phellandrene group of greater than 50% of total terpene composition. The Rocky Mountain populations contain evidence of the presence of santene, *alpha*-pinene in amounts greater than 3.5%, camphene greater than 7%, and the *beta*-phellandrene group less than 50% of the total terpene composition. These results argue for Hunt and von Rudloff's (1979) recognition of *Abies bifolia* as specifically distinct from *Abies lasiocarpa.*

Acknowledgments

Facilities of the chemistry department of Humboldt State University were used for analyses. I thank J. Hennings, Professor of Chemistry, for his assistance and, especially, J. O. Sawyer for his advice and assistance in all phases of this project.

Literature Cited

Boivin, B. 1959. *Abies balsamea* (Linné) Miller et ses variations. Naturaliste Canad. 86:219–223.

Fowells, H. A. 1965. Silvics of forest trees of the United States. U.S. Dept. Agric. Handb. 271.

Franklin, J. F. and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA For. Serv. Gen. Techn. Rep. PNW-8.

Hunt, R. S. and E. von Rudloff. 1974. Chemosystematic studies in the genus *Abies,* I. Leaf and twig oil analysis of alpine and balsam firs. Canad. J. Bot. 52: 477–487.

——— and ———. 1979. Chemosystematic studies in the genus *Abies,* IV. Introgression in *Abies lasiocarpa* and *Abies bifolia.* Taxon 28:297–305.

Liu, T. S. 1971. A monograph of the genus *Abies.* Dept. Forestry, College of Agric., National Taiwan Univ., Tapei.

Oakeshott, G. B. 1971. California's changing landscapes. McGraw-Hill Book Co., NY.

Sawyer, J. O. and E. A. Cope. 1982. *Abies lasiocarpa* (Hook.) Nutt. Madroño 29: 218.

———, D. A. Thornburgh, and W. F. Bowman. 1970. Extension of the range of *Abies lasiocarpa* into California. Madroño 20:413–415.

von Rudloff, E. 1975. Volatile leaf oil analysis in chemosystematic studies of North American conifers. Biochem. Syst. Ecol. 2:131–167.

Whittaker, R. H. 1961. Vegetation history of the Pacific Coast states and the "central" significance of the Klamath Region. Madroño 16:5–19.

Zavarin, E., W. B. Critchfield, and K. Snajberk. 1971. Composition of the cortical and phloem monoterpenes of *Abies lasiocarpa.* Phytochemistry 10:3229–3237.

——— and K. Snajberk. 1972. Geographical variation of monoterpenes from *Abies balsamea* and *Abies fraseri.* Phytochemistry 11:1407–1421.

———, ———, T. Reichert, and E. Tsien. 1970. On geographical variability of the monoterpenes from the cortical blister oleoresins of *Abies lasiocarpa.* Phytochemistry 9:377–395.

(Received 23 Oct 1981; revision accepted 19 Apr 1982.)